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CADANG-CADANG DISEASE OF COCONUT

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

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I. INTRODUCTION

In accordance with the request of the Government of the Philippines for further technical assistance in the investigation of the destructive cadang-cadang disease of coconut, the Food and Agriculture Organization of the United Nations, under its Expanded Technical Assistance Program, appointed Dr. Karl Maramorosch as Plant Virologist, to advise and assist the Government in the implementation of a research program designed for determining the cause of the disease, the methods of its transmission and other factors relating to its epidemiology, with the aim of devising appropriate control measures. The expert served in the Philippines from 16 February to 21 July 1960.

Dr. Maramorosch was preceded in the Philippines by two FAO experts, namely, Dr. Frank P. McWhorter who served from March 1958 to April 1959, and by Dr. W. C. Price who served from 8 November 1956 to 14 October 1957.

Before coming to the Philippines, the expert visited the Indian Central Coconut Research Station at Kayangulam, Kerala State, South India, to get acquainted with the Travancore wilt disease of coconut and the research on coconut diseases in India.

In view of the comparatively short period of assignment, the expert spent nearly full time at the Guinobatan Experiment Station which is located 540 kilometers from Manila. During his stay, the expert was requested to aid the Bureau of Plant Industry also in the study of other coconut diseases: the boang disease of south-eastern Mindanao and the internal spotting disease on the Island of Mindoro. Brief summaries on these two diseases are appendixed to this report.

In carrying out his assignment, the expert was greatly aided from the day of his arrival by the wholehearted support of the members of the Department of Agriculture and Natural Resources, in particular the Honorable Acting Secretary Jose Trinidad and the Director of the Bureau of Plant Industry, Dr. Eugenio E. Cruz. The investigation of the expert was facilitated and suggestions were rapidly implemented by the enthusiastic and able staff of the Guinobatan Experiment Station, especially by Avelino E. Bigornia, Acting Superintendent and Entomologist, and Mr. Carlos A. Calica, plant pathologist. These competent research workers have been carrying out for many years long-term studies on cadang-cadang at the Guinobatan Experiment Station.

The expert is especially thankful to Mr. Bernardo S. Castillo, Chief of Plant Pathology of the Bureau of Plant Industry and Research Coordinator of the Guinobatan Experiment Station, who accompanied the expert on many trips and whose knowledge, advice and close friendship made the task much easier than it would otherwise have been.

The expert is also grateful to Dean Dioscoro Umali of the University of the Philippines College of Agriculture in Los Banos, and to Dr. C. V. Crucillo, Director of Foreign Aid Coordination, National Economic Council, for many helpful suggestions.

The aid and support of Mr. J. N. Corry, United Nations Resident Representative in the Philippines, and his staff (in particular Miss Eva Santillan) are gratefully acknowledged.

Special thanks are expressed to Mr. James Adams of the British Embassy and Mr. D. C. Mandeville, Scientific and Technical Adviser on Colombo Plan matters for their interest and help in the cadang-cadang project.

Mr. Eugene Ranson, Agricultural Attaché of the U. S. Embassy in Manila, supplied certain publications and facilitated the work in other ways. Thanks are also due to Mr. Hans Rothkirch, Assistant Manager of Franklin Baker and Company of the Philippines for his continuous interest in the cadang-cadang studies.

The expert is grateful to Dr. Robert F. Chandler, Jr. and Dr. Sterling Wortman, Director and Assistant Director, respectively, International Rice Institute, with whom the expert had many pleasant discussions about the investigations. Dr. Wortman's visit to the Guinobatan Experiment Station and his active help in formulating further plans for the selection of resistant coconut palms as incorporated in the present report is especially appreciated.

Thanks are due to Mr. Adrian Ace Williams of New York, who during his visit to the Philippines gave his time freely to provide a set of beautiful color photographs of cadang-cadang symptoms, which will be printed for distribution in the Philippines.

Through the help of Colonel Edmund W. Szaniawski, Commander at the U. S. Air Force Base at Clark Field, a fully equipped reconnaissance plane was made available to the expert for an aerial survey of Bondoc Peninsula.

Thanks are due to Professor Dr. J. P. H. van der Want, Director of the Flower Bulb Research Institute at Lisse, the Netherlands, for cooperation in the attempted serological studies of cadang-cadang and other coconut diseases.

The hospitality shown the expert by Dr. K. P. V. Menon, Director, Central Coconut Research Station, Kayangulam, Kerala State, South India, and his staff, will always be remembered with great pleasure.

II. CURRENT VIEWS ABOUT THE NATURE OF CADANG-CADANG

As already pointed out in previous FAO reports Nos. 850 and 1107 (9, 10), symptomatology of cadang-cadang and field observations of its spread support the view that cadang-cadang is caused by an infectious agent belonging to the group of insect-borne plant viruses. Other possible causes are still being considered by a small group of workers, but these hypotheses, particularly those concerned with nematode injury and nutritional disturbance, can probably be eliminated on the basis of present information. A detailed account of this particular aspect can be found in FAO report No. 850. Reference will be made to one of the earlier quoted cases, that of a plantation in Barrio Quitago, Guinobatan, where in a small plantation coconut trees were planted in pairs around 1897. In 1960, that is 63 years later, when this plantation was visited, some pairs were still healthy, while others were diseased, but in several instances one tree of a pair was in an advanced stage of the disease, while the other was still perfectly healthy. As already pointed out by Price in 1957, since the roots of trees in such pairs are closely intermingled and thus in contact with the same soil solution, they would be expected to respond about equally to a nutrient deficiency of the soil in which they are growing. There is no evidence that the trees in this plantation differ as to variety. Chance infection by an extraneous virus, carried by an airborne vector, is the most logical explanation for the findings. The opinion that the disease is caused by nutritional imbalance has not been supported by members of the Bureau of Soils. Nevertheless, and in spite of all the evidence to the contrary, a few people fanatically adhere to this hypothesis, although their own field trials and those of others completely failed to substantiate their claims. Administrative officials and the public are often exposed to fantastic claims that cadang-cadang disease is caused by "The Voice of the Mayon Volcano" and/or by radioactive materials ejected from the crater of the Mayon volcano. Such statements were frequently published by the daily press in 1960, in articles signed by physicians, public accountants, and even university professors. These articles caused confusion among the public and made coordination of research on this important disease difficult.

Until very recently lack of an adequate and complete description of cadang-cadang symptoms made proper diagnosis difficult. Misjudging other disorders, and particularly all sorts of yellowing, as due to cadang-cadang, resulted in several claims of sensational cures, or in claims of mechanical transmission of cadang-cadang. Actually, no cadang-cadang diseased tree has ever recovered, and no tree has been experimentally (mechanically) infected. Newspaper articles about the disease have presented its cause as an unsolved mystery and obscured the seriousness of the problem and its impact on the economy and life of the Filipinos. By 1960, in the Bicol provinces and neighboring areas an estimated ten to thirteen million trees have succumbed to this dreadful malady.

III. SYMPTOMATOLOGY OF CADANG-CADANG

In a recently published brochure of the Bureau of Plant Industry, Calica and Bigornia (3) listed the characteristic symptoms of the cadang-cadang disease. The disease cannot be diagnosed authoritatively until after it has advanced considerably. The following description of its syndrome is based on observations made at a stage after one can fairly accurately tell that a coconut palm is affected by the cadang-cadang disease.

1. On pinnae of young leaves the earliest symptom is the development of tiny roughly circular, bright yellow, translucent spots on the veins. The spots become evident on these leaves as soon as they have unfolded from the bud and have developed sufficient chlorophyll to be dark green in color. Although the spots can be observed on young leaflets, only on mature leaves their number and size increase so as to impart a characteristic pattern of the cadang-cadang yellow mottle decline.

The lower surface of mature coconut leaves shows irregular "water-soaked spots". Mature coconut leaves display yellow streaks as a result of enlargement and fusion of adjacent spots. The veins and veinlets become cleared in a very characteristic, although not very pronounced way. The basal portion of the petiole of a healthy tree differs strongly from those of a diseased one, because the stipules of diseased trees remain attached to the base of the petiole, giving it a winged appearance. The fronds of a diseased tree are borne in an upright position in the crown. Eventually, the crown of the diseased tree becomes reduced to a mere tuft of small, brittle fronds at the apex of the trunk. Diseased trees yield more nuts in the initial stages of the disease than do healthy trees, but these nuts are smaller, rounded at the base or misshaped and scarified with brown streaks. Nuts from a healthy and diseased tree, when cut open, show that in the early stage of the cadang-cadang disease reduction in size of nuts is due to a reduction in the thickness of the husk and also in that of the meat. A comparison of healthy and diseased inflorescences shows an abundance of female florets (buttons) on the healthy and fewer on the diseased. The healthy inflorescence is widely open, while the diseased one is reduced in size and retains a characteristic upward position of its branches. The color of diseased roots differs from that of healthy ones, and the higher-order roots abound on the healthy but are lacking on the tertiaries and quarternaries of the diseased trees.

The fronds of diseased palms are stunted and more brittle than those of healthy trees. Reduced in length and in size of leaflets, the fronds gradually assume an erect position in the crown. Affected fronds dry up faster, die and drop off. This results in a gradual

reduction in the total number of fronds until a small, yellowish-green or yellow tuft is left at the apex of the trunk. Finally, the bud dies, falls off, and leaves the crownless trunk standing. A plantation in this stage looks like a field of telephone poles.

Coconut palms seldom become diseased before flowering, probably because the incubation period of the disease is fairly long. In the rare cases of early infection, when the disease strikes before flowering sets in, leaves are spaced somewhat farther apart than on healthy trees of the same age. Therefore, the resulting leaf scars are more widely spaced. The stem of such trees tends to taper markedly towards the crown. The reverse is true on trees affected after fruiting. On these leaf scars are closer together than those lower down on the trunk or those on healthy trees. The trunks are sometimes tapered, but in most cases tapering is not evident. Nuts are produced only in early stages of the disease. Later fruiting is much reduced and the nuts are reduced in size and distorted. After a period of from one to four years from the onset of the disease, production of nuts ceases. Trees that have stopped producing nuts have never been observed to resume flowering. When the disease strikes before flowering, the trees never bear nuts.

It was found recently by Calica and Bigornia that coconut palms affected by the disease show even in the initial stages of infection a marked deterioration of the root system, particularly of roots of higher orders. The growing point of these roots rots and eventually the whole absorptive zone is destroyed. The massive destruction of the feeder roots of diseased palms simulates symptoms of a nutritional disturbance.

Foliar symptoms do not develop first on older leaves, as was thought earlier, but can be seen first on the young leaves, becoming more pronounced on older ones.

The progress of the disease is slow, with a five to ten year interval between the appearance of first symptoms and the death of the trees. In exceptional cases, due probably to the vitality of individual palms and environmental conditions, this period may extend to over twelve years. This slow progress may explain the erroneous impression that cadang-cadang strikes only after coconut palms attain bearing stage, and that it is limited to older trees.

It has been stressed by Calica and Bigornia that none of the characteristic disease symptoms listed above can be considered as a unique sign of the disease. On the contrary, each one of these symptoms, whenever applicable, should be considered as an essential part of the cadang-cadang syndrome, and only when taken together can these symptoms be used in identifying the disease.

It is hoped that the color photographs of cadang-cadang taken by Mr. A. A. Williams and the expert will be published, which would be undoubtedly helpful in the diagnosis and eventual control of the disease.

IV. CADANG-CADANG IN RELATION TO OTHER COCONUT DISEASES

On his way to the Philippines, the expert visited the Central Coconut Research Station at Kayangulam, Kerala State, South India, where he observed at first hand the symptoms of another important coconut disease, the Travancore wilt. Through the kind cooperation of Dr. Menon, Director of the Station, and of several members of his staff, in particular Mr. Davis, the expert became acquainted with the progress of research and the symptomatology of the Travancore wilt. While in the Philippines, the expert was in close contact with Professor Dr. van der Want, who together with Professor T. H. Thung in 1960 visited Togo, French Africa, where the Kaincopé disease of coconuts occurs. From the information gained through them, and from his own observations in South India, the expert concluded that the diseases of India and Africa are not similar to cadang-cadang. To date it seems that cadang-cadang is limited in its range to the south-eastern provinces of Luzon and neighboring islands, and does not yet occur elsewhere in coconut-growing areas. The limited occurrence of a plant virus disease is not at all unusual, but in the past it has often been experienced that such diseases, starting in a limited area, spread throughout the world. The potential threat of cadang-cadang is evidenced by its ability to cross from one island to another. The distance between various islands of the Philippines and between the Philippines and other neighboring coconut-growing countries are fairly small. Therefore, the cadang-cadang studies should be of concern not only to the Philippines but to other countries as well.

V. DISTRIBUTION OF THE DISEASE

Until recently the presence of cadang-cadang seemed limited to the Bicol provinces: Sorsogon, Albay, Camarines Norte, Camarines Sur, Catanduanes, Masbate, and Samar. Leyte has reported no outbreaks as yet, although in the opinion of the expert, the disease will soon be found there too. This seems to be unavoidable because of the unfortunate belief of many coconut farmers that tambulilid-type coconut palms from Bicol are resistant to cadang-cadang. Although in FAO Report No. 850 this claim was disproved, seedlings of tambulilids were, and still are, transported by the thousand from Bicol to the Island of Leyte. A certain percentage of these smuggled seedlings (the Bureau of Plant Industry banned all coconut material from Bicol for shipments outside the diseased area) inevitably is infected with cadang-cadang by the time of transplanting, because the seedlings are grown in the open for several months in the devastated areas.

In June 1957 the first diseased coconut palms were found in the Bondoc Peninsula of Quezon Province. For lack of roads it was extremely difficult to find diseased trees there using conventional transports and observations. Through the kind cooperation of the U.S. Air Force, the expert obtained, in 1960, a small reconnaissance plane for an aerial survey of this inaccessible region. Earlier flights over Bicol in commercial planes, although at higher speed and altitude, convinced the expert that this method would be suitable for detecting diseased trees. It was found that trees showing cadang-cadang symptons were quite conspicuous to an airborne observer for distances of up to one kilometer from altitudes of 200 to 300 meters.

The survey was conducted on 12 July 1960. The flight was made, following a general outline plotted on maps, kindly provided by the U.S. Air Force, and necessary deviations from the route were made whenever requested by the expert. Total flying time was approximately four hours, and the speed did not exceed 80 miles per hour.

It was found that cadang-cadang-diseased trees occur on both sides of the Bondoc Peninsula and that the invasion had begun fairly recently. Because of the importance of these newly infected areas, near the main coconut-growing areas of the Philippines in Quezon and Laguna, a detailed account of the survey follows.

VI. AERIAL SURVEY IN THE BONDOC PENINSULA, QUEZON PROVINCE

On 12 July 1960, shortly after 8 a.m., the expert boarded a U.S. reconnaissance plane at the Manila Operations Base of the Philippine Air Force. The expert was accompanied during the flight by Mr. J.N. Corry, Resident Representative of the United Nations in the Philippines. The plane headed from Manila to Gumaca, flying very low along the coast, then went inland and across the peninsula to Catanauan and General Luna, circling around these localities. From Catanauan the route proceeded towards Mulanay, San Isidro, Lipata, Vocal, Sagongon, Canowep, Yuni and Vocal, cut across to San Narciso, flying over Punta, Rizal, San Narciso, and Buenavista. On the return Cogorin, Ilaya and Bacungan were passed. North of Bucal the last cadang-cadang observations were made.

Between Unisan and Gumaca, a few kilometers from the coast, there were a few scattered trees with early signs of cadang-cadang. More advanced stages were seen isolated along rice fields and on hills close to Unisan, approximately eight kilometers north of Agdangan. Numerous dead trees were spotted near Catanauan. On the stretch between Caluag and Catanauan, diseased trees were observed east of Bacungan and north as well as around Cogorin. Sandoval Point peninsula between Tayabas and Catanauan was severely affected, with dead trees in fairly large numbers. South of Catanauan near Aju Point, beginning stages of disease were observed. A few diseased trees were seen north and south of Ajos. On the west coast the incidence of the disease seemed to increase in intensity towards the barrio Buenavista and Mulanay. Isolated cases were also spotted near Sagongon and Canowep. Very few infections were seen near Yuni. At this point, the plane turned eastward and crossed the peninsula. In the vicinity of San Narciso, on the east coast of Bondoc, from Buenavista to Rizal and Punta, a severely devastated area with dying and dead trees indicated that the disease had been present there for several years.

After the plane left Bondoc Peninsula, heading toward Clark Field, a few infected trees were seen in Lucban and Sampoloc. These isolated trees were dinstinct from the rather common yellowing occurring in this area in concentrated patches, and particularly common in the vicinity of Santa Cruz.

Although the aerial survey proved very useful in the study of cadang-cadang distribution in newly affected areas, it should be followed by conventional surveying methods from the ground. These surveys should concentrate on areas where diseased trees were spotted, even if such areas are far from accessible roads, highways and railroad stations.

Although the spread of cadang-cadang by an insect vector has not been demonstrated experimentally, the creation of a buffer zone between Bondoc Peninsula and the major coconut-growing area could be undertaken with comparatively little expense at the present moment. Regular spraying and dusting with insecticides could not be expected to stop completely the eastward progress of the suspected insect carrier, but it could conceivably slow down the disease progress. Such a buffer zone, a strip of land east of Gumaca across the narrow part of Luzon Island, could be sprayed regularly once a month from one of the planes used now by the Bureau of Plant Industry for locust control. However, this work should only be undertaken if assurance of regular applications and supply of insecticides could be given. If a strict time-table could not be followed, the whole operation would be a waste of funds. Roguing of diseased trees can hardly be expected to stop the spread of the disease, because the incubation period is most likely longer than three years and many infected trees could serve as sources for further infections long before they could be diagnosed as diseased and removed. Also, it appears very likely that many other plants in the palm family, and perhaps plants outside of this family, serve as alternate hosts of cadang-cadang. Nevertheless, roguing should be encouraged in newly invaded areas, not to stop, but to slow down the further progress of the disease. Questionable early cases of cadang-cadang should be marked with an easily-distinguishable oil-painted question mark, while trees diagnosed beyond doubt as diseased, should be marked in a different way, perhaps with a white cross. The latter trees should be destroyed. It is important that marking of trees be done by only one government agency, preferably by teams of the Bureau of Plant Industry, at present best qualified for this task. The participation in this effort by other organizations in the past led to great confusion, particularly when suspected, but not actually diseased trees were found to have recovered. The use of different markings for suspected and definitely diseased trees should therefore be emphasized and strictly followed. Eventually, when enough workers will have been trained in cadang-cadang diagnosis at the Guinobatan Experiment Station, permanent teams could be assigned for surveys and marking of cadang-cadang trees.

VII. LOSSES CAUSED BY CADANG-CADANG AND EPIDEMIOLOGY

Conservative estimates give the number of dead trees in the Bicol provinces as 10,000,000. Between one third and one half of the production has been eliminated by the disease in many areas. Accurate estimates are not possible for many reasons. No grower has ever been able to quote the exact number of trees on his plantation, even when the plantation was only one hectare in size. Usually, figures are based on individual estimates and the number of trees originally planted on an area is considered as the number of trees present, although losses and replanting may have changed this original number in various ways. Copra exporters have often pointed out that in spite of cadang-cadang losses, no appreciable decrease in copra exports from the Philippines has occurred. This, if correct, can easily be explained by the increased production of many younger, newer coconut plantations.

A few years ago the spread of cadang-cadang could still be studied by the observation of five-hectare plots and by strip surveys (FAO Report No. 850). These methods are no longer of value because many trees have disappeared because of the disease. Often, despite an actual increase in the disease incidence, an apparent decrease is being recorded because diseased trees that have been cut in the past are not counted, and only the few still left on a plantation are taken into consideration.

Epidemiological plots could still be of value in newly infested areas in Quezon Province, but they are of no avail in Bicol.

VIII. THEORIES REGARDING THE SPREAD AND NATURE OF CADANG-CADANG

As already pointed out, the symptomatology and epidemiology of cadang-cadang strongly support the view that the disease is infectious and is caused by a virus. The infectious nature of the disease is apparent to any careful observer. Its constant and relentless spread on all kinds of soils, irrespective of fertilization and cultural practices, is an obvious indication of its infectious nature.

It has long been noticed by coconut planters that certain factors seem to favor the faster spread of the disease. Some of these factors have even been considered by themselves the sole causes of the malady, and not as contributing factors in its spread. These factors are : typhoons, the outbreaks of Mayon volcano, and introduction of large herds of cattle into coconut plantations. Whether these seemingly unrelated factors could have a common denominator in the etiology of the disease could not yet be tested experimentally, but a working hypothesis can be advanced, to explain why coconut planters could have been justified in blaming each and all of these factors for new, widespread outbreaks.

Typhoons have not resulted in the immediate spread of cadang-cadang, although after severe typhoons, and a lapse of a few years, new areas of destruction were invariably recorded. As already noted earlier, the suspected incubation period of the disease in the coconut palm is three to four years. If this is the time lapse required for the development of symptoms after the plants were inoculated by an insect vector, the exposure to the vector might have occurred during the typhoon.

The outbreaks of Mayon volcano in 1938 and somewhat less so in 1948, have reportedly also been followed by new spread of cadang-cadang. It could well be that ashes of the volcano covered the preferred host plants of the as yet unknown vector and prevented its feeding on these plants. In this emergency, as in the case of the typhoon disturbance, the vector might have probed the coconut in search for food. The erratic and slow spread within a plantation and from locality to locality strongly favors the view that the vector is not a common feeder on coconut.

Finally, the introduction of large herds of cattle into cadang-cadang-infected regions has been linked by some planters with new outbreaks of the disease. Again, as in the two previous instances, the ecological balance might have been disturbed when cattle ate a hypothetical common host plant of the vector and the carriers of the virus were forced to seek other possible food plants.

The above hypothesis is given here only as a working hypothesis; it might be worthwhile, to test it experimentally in view of the observations of many coconut planters in Bicol. In this connection, it should also be pointed out that the original outbreak of the disease on the Island of San Miguel off Tobaco, around 1926, was recorded near the cattle coral.

Nutritional imbalance cannot be supported by any evidence in the case of cadang-cadang, and, on the contrary, all available evidence is against this hypothesis. For reasons that are difficult to understand, a small number of workers in some institutions still cling to this hypothesis, disregarding the fact that cadang-cadang constantly continues its devastating progress on all types of soil.

IX. GUINOBATAN EXPERIMENT STATION: STAFF AND FACILITIES FOR RESEARCH

The Guinobatan Experiment Station in Guinobatan, Albay, where the research on cadang-cadang of the Bureau of Plant Industry is being carried out has a total area of 63 hectares, of which about 38 hectares are under coconut. Until 1960, the Station, like all other experiment stations of the Bureau of Plant Industry, was under the administrative supervision of a regional director. At the suggestion of the expert, this arrangement has been changed to streamline the research, to facilitate communications with the central office and to speed up the financing of projects. The Station is now placed under the direct supervision of the Director of the Bureau of Plant Industry. Another change concerned the functions of the station superintendent. Previously, the superintendent was responsible for the whole research program as well as administration. As this arrangement appeared disadvantageous for the progress of the research, a new position of research coordinator was created, who is responsible to the Director of the Bureau for all matters concerning the research at the Station. A part-time reference librarian was also added to the staff.

Although some projects on abaca, citrus and seed improvement are still continued at Guinobatan, the major effort of the staff is devoted to cadang-cadang research. In the middle of 1960, the following research projects were under way : disease transmission by insects, mechanical means, dodder and grafting; selection for resistance from local varieties; serology; studies of soil microflora and nematodes; disease surveys; insect and mite feeding as cause of leaf injury; studies of root injuries. Research projects were also outlined in agronomy, chemistry and botany.

During the stay of the expert in the Philippines, and partly as a result of his suggestion, a Coconut Research Group was created to intensify and strengthen all the research projects of the Bureau of Plant Industry for the improvement of the coconut industry, particularly those that may lead towards the early solution of the coconut cadang-cadang disease problem. The equipment and facilities of the Station were substantially increased. FAO also provided additional photographic equipment to complete the photographic set-up at the Station.

The expert drew up plans for modernization of the laboratory facilities and the completion of the building in such a way as to provide additional space for the increased scientific staff and for visiting investigators. The construction of additional greenhouses and of an insectory was also suggested, and plastic screen was ordered for this purpose from abroad from FAO funds. To increase the available water supply FAO provided a sum for the purchase and construction of cisterns. A small number of cement cisterns was made available through the kind intervention of Mr. S. de Erquiaga.

X. NEW APPROACHES TO THE STUDY OF CADANG-CADANG DISEASE

Cadang-cadang has been recognized as the most serious threat to coconut production ever recorded in the Philippines, and as a potential threat to coconut production in other copra-producing areas. It has been fully realized that the study and research of this disease has to be carried out over a period of many years and that no immediate cure or prevention can be anticipated. Only a long-range program of research, with assured financial support for an adequate number of years, can solve the problem.

Insofar as the principal research goals are concerned, the demonstration of the viral nature of the causative agent and of its spread are most important. From a practical viewpoint, the developing of resistant coconut trees is the only logical solution for the prevention of cadang-cadang in the future. The economic losses could be overcome in part by the introduction of new methods of coconut cultivation, in particular by an unprecedented practice of crop rotation, that will be discussed in this report.

Transmission Studies

Numerous species of insects were collected in the Bicol region and tested for possible transmission of cadang-cadang on coconut seedlings and, to a lesser extent, on other plants. These studies were carried out by Mr. Avelino E. Bigornia, and Mr. Carlos A. Calica. All these attempts have brought no results so far, but they ought to be continued. In addition to common coconut feeders, other insects, not usually associated with coconut, should be included in large-scale tests. It is expected that these transmission studies will be intensified through the additional entomologist recently appointed to the staff.

It has been tried in the past to transmit an infectious agent from coconut to herbacious hosts by mechanical means. Although these tests should be further continued, the expert felt that transmission trials by the use of dodder (Cuscuta sp.) might be more likely to succeed. The technique of dodder transmission was demonstrated to the workers at Guinobatan, and an ample supply of seed obtained. The first indications that herbacious hosts, for instance, tomato plants, may become infected by dodder transmission were obtained just before the expert's assignment terminated. It is hoped that intensive tests with dodder will reveal additional experimental hosts of cadang-cadang.

Although tests initiated by Dr. Price in 1956/57 on mechanical transmission and on insect transmission to coconut, have given no results so far, the test plants should be watched carefully in following years. Actually, no results could have been expected by

1960 in view of the long incubation period of the disease in coconut. The finding of herbacious hosts by the use of dodder could conceivably reveal hosts in which the disease would be recognized within a much shorter period of time than in coconut.

Host Range of Cadang-Cadang

If cadang-cadang were limited to coconut palms, roguing would have been a drastic but effective method for its eradication. There are, however, good reasons to believe that several alternate host plants occur in the devastated regions. In addition to all varieties of coconut that were found infected, de Leon and Bigornia, and later McWhorter, listed a number of other palms with symptoms of cadang-cadang. This indicates that control by roguing has little chance of success. Pandanus coplandii Merrill also was found with spots, suggestive of cadang-cadang infection. These small plants can be studied much easier than the tall coconut palms, and they promise to aid in further studies.

Root Transfusion

A method for virus transmission in coconut, developed by Davis in India and used there successfully for the transmission of the Travancore wilt, has been demonstrated and tried at the Guinobatan Station for the experimental transmission of cadang-cadang. It was suggested by the expert that this promising technique should be used on a large number of trees, with adequate controls.

Serology

Mr. Castillo and the expert collaborated with Professor J. P. H. van der Want of the Institute of Flower Bulb Research in Lisse, the Netherlands, in the initial attempts to develop an anti-serum for diagnostic purposes of cadang-cadang. Professor van der Want's interest in the comparison of various "mysterious" coconut diseases of the world and the need in the Philippines for a test to assure the early diagnosis of the disease resulted in the initiation of these combined efforts. Diseased material has been dispatched by air to the Netherlands, where it is now awaiting further trials. It is expected that serological tests in the Philippines will be intensified with the help of the equipment and supplies purchased through the Colombo Plan.

Rejuvenation of Coconut Trees for Experimental Use

While in India, the expert saw at the Kayangulam Experiment Station artificial rooting near the crown of old coconut palms. Such trees were later cut and transplanted and for a few years had the appearance of dwarf trees with all the advantages for close observation of disease symptoms. At the Guinobatan Station a few trees were prepared for such rejuvenation by constructing and attaching large wooden boxes high up on coconut trees just below the crown and filling these boxes with peat and soil, kept moist all the time. Rooting was expected to take from eight to twelve months, and after this time the trees were to be cut and replanted. This artificial lowering of the trees will enable scientists to make their own close inspections and insect collections on diseased leaves and inflorescences, without depending on the skill of climbers and third-hand information gained from unskilled laborers.

Selection for Resistance

Two immediate and urgent problems, in addition to the already mentioned research approaches, will be discussed here in detail. The first concerns selection of coconut palms that would be resistant to cadang-cadang. This is a long-term undertaking. The second deals with a practical solution of the problem in the nearest future to overcome the economic losses in the next few years.

Selection for resistance began at the Guinobatan Station when the FAO expert Dr. McWhorter initiated the selection program in 1959. The incubation period of cadang-cadang is at least three years, which would not permit classification of resistant or susceptible seedlings in a short time, even if it were possible to transfer the disease readily by means of a vector or mechanically, or by means of dodder.

The coconut is largely cross-pollinated, probably by insects. Wind may also affect cross-pollination. A tree may begin to bear nuts after four to six years, but a susceptible seedling may not exhibit symptoms of cadang-cadang for fifteen to twenty years or more after germination, even in the area of severe devastation. The interval required between crossing, classification of resistance, and crossing would therefore be fifteen years or more.

At the moment there is no known method for rapid vegetative multiplication of a coconut seedling. Vegetative propagation would allow much better study of individual seedlings (genotypes) and would then permit quick multiplication of any seedling found definitely to have resistance. The work of Davis (5) in India indicates that it is not impossible to obtain vegetative propagation in coconuts, and this problem should be given serious attention in the future.

One aspect of basic research should be strongly encouraged. If one could stimulate the depressed basal buds of coconut to develop, vegetative propagation of coconut palms would be possible. This would have a great impact on developing resistant varieties and on improvement of existing types of coconut palms.

If the disease continues at its present or an accelerated rate to spread from Bicol to other regions, any breeding method involving hybridization or in-breeding, probably would give results too late to save the coconut industry of the Philippines, because of the long period between crossing and final evaluation of resistance.

In order to obtain reliable evaluations of seedlings or families of seedlings, very large populations of trees must be grown. Therefore, the large numbers of seedlings to be evaluated should be used as the "replants" on presently devastated plantations. As the Government does not own large coconut lands and the support of a selection program would be very costly, the program suggested below for cadang-cadang resistance selection should be carried out by interested and carefully chosen planters as part of their regular replanting operations. The program could be adopted by planters at a very slight cost above that of normal replanting. There is no assurance that the program will provide resistant strains of coconuts, but there is a chance, and there should be improvement in yielding ability and earliness.

If a plantation proved successful, enough seed nuts would be obtained at a sufficiently early date in order to help materially the coconut industry, and nuts of the improved strain should sell at a considerable premium. This would compensate the plantations for the additional care and work required.

The program of selection, started in 1959 at Guinobatan Station (2), should be continued and expanded in the following way : One or more plantations in the devastated areas, desiring to cooperate in a good selection program on a large scale, should be found . Qualified technical men should select, on each plantation, as many healthy, good trees in devastated areas as can be found, but not more than the number required to produce the necessary nuts for replanting. Each tree should be given a permanent number.

First year : Harvest nuts from selected trees, and germinate them. Label each seedling with number of parent tree and number of seedling from that parent tree. (Example: 1-1, 1-2, to 1-n; 2-1, to 2-n; etc.).

Second year : Check all mother trees for continued health. Harvest nuts from healthy trees, germinate seedlings, number them, use for replanting. It is suggested that a map, indicating the position of the mother trees within a plantation, be prepared, so that in future years other workers can with ease locate these trees for inspection purposes.

Third to fifth year : Same as second year.

Sixth year : Check mother trees and any producing replants of previous years for continued health. Harvest nuts only from mother trees which have produced still healthy seedlings.

Future years : Mother trees and all seedlings should be checked annually for symptoms of cadang-cadang. In addition, notes should be taken on yield (by copra weight, rather than by nut number!), earliness, and other characters of interest on all seedlings from still healthy mother trees.

As soon as there is sufficient evidence that some families of seedlings are definitely better than others, all nuts from all healthy seedlings from all better families should be bulked together to form a single lot of seed nuts for commercial plantings.

At each harvest date thereafter, the most recent notes on other characteristics should be considered in determining the families to be bulked.

At least yearly, perhaps oftener, qualified technical people of the Bureau of Plant Industry, College of Agriculture, and other organizations, should visit the cooperating plantations to inspect the program and records of these visits should be entered upon the pedigree record books of the plantation. A supply of such books is at hand at the Guinobatan Station. These entries would provide proof over the years, of the quality of the selection work and would provide a basis for later certification of seed nuts offered for sale by the plantation.

Hybridization probably should not be attempted until resistance of mother trees has become evident as judged by performance of many seedlings used as replants. When such evidence is available, crosses among resistant trees might be made, and the resulting nuts germinated, grown in isolation if possible, and allowed to interpollinate. This would provide synthetic variety, but many years would be required to complete the project (an estimated 30 years or more).

Inbreeding had been started in 1959 by workers of the Guinobatan Station. This work should be continued, in the hope of finding an inbred line high in resistance which could be used later for development of synthetics. This also will require a very long time and would require the planting, for evaluation, of many trees of low production. It would be costly in many ways, and therefore its continuation is not being advised.

World Bank of Coconut Varieties

A number of coconut varieties have been described by scientists from various countries (8). Should one of these be resistant, it could help the Philippine industry within a relatively short period, fifteen to twenty years from the date these varieties were introduced. Through the assistance of FAO, requests have been sent to coconut growing countries for supply of seed nuts, but replies have so far been received only from a few sources. The expert came therefore to the conclusion that the introduction of foreign varieties must not depend on written requests, but should be carried out by a coconut specialist, who can travel to all coconut areas of the world and make the selection personally in each area. About 100 nuts of each variety should be obtained. Only in this realistic manner can the proper selection of seed nuts and their immediate shipping be assured. The total cost of this operation would be insignificant in a project of such importance.

The collection thus obtained would form the center of a world bank of coconut varieties. One half of the nuts of each variety should be grown in one of the most devastated areas of Bicol, preferably on the Island of San Miguel. The other half should be propagated at a great distance from this area, to assure healthy material for as many years as possible. Government land could be made available for this purpose, south from Zamboanga (off Mindanao), on Basilan Island, at the College of Agriculture.

If a foreign variety appears promising in the Philippines, additional nuts may be obtained from the source, or by making crosses among trees of that variety. In the future this bank will be able to supply propagating material for research purpose to various coconut producing countries for the benefit of all.

Replanting and "Crop Rotation"

In 1953 research workers of the Bureau of Plant Industry and coconut growers, in particular the late B. de Erquiaga (7) conceived the idea of intensive replanting of devastated areas. It seemed that the industry, as well as the livelihood of many families in the Bicol,

could be saved by replanting and re-establishing of devastated areas (1). Even if coconut palms will ultimately be killed by the disease in about 30 years, the palms would have an average of 20 years of productive life to compensate the grower for his expenses and to maintain a balanced budget for his family.

A small plantation with 206 trees was started in Ligao, in the vicinity of the Guinobatan Station seven years ago. Although the nuts came from ordinary Laguna-type coconuts that are known to bear after seven to ten years, the additional care in management and fertilization resulted in the unexpected bearing of large numbers of trees after only four years. After seven years, nearly 70 percent of the trees were bearing. Only one out of 206 trees showed first signs of cadang-cadang in the seventh year of the plantation.

This experiment showed that replanting, even with susceptible coconuts, can bring results that ought to overcome the heavy losses caused by the disease.

At first it was thought that interplanting, and replacing of dead trees would be advisable. After discussing this problem with Dr. C. V. Crucillo, Director of the National Economic Counil, the expert came to the conclusion that a sort of "crop rotation" would be more advisable. If, for example, a planter had ten hectares of a devastated plantation in the Bicol, he should plant five hectares with coconuts, and the other half with, say abaca. After 25 (or 30) years, all coconut trees should be cut, irrespective of their state of health, and abaça planted in their place. The abaca lot should at the same time be used for a new coconut grove. This system of rotation would eliminate the heavy losses now incurred by coconut planters in Bicol. It would require an intensive publicity drive by all available means of communication, to change the old attitudes of coconut planters who consider at present coconuts as a life-time, permanent crop of 60 to 100 years.

An outline for a popular pamphlet has been prepared by the expert, describing the selection, replanting and "crop rotation" for coconut growers in the provinces affected by the disease. The publication could have editions in English, Tagalog and Bicolano. The expert suggested the inclusion in the text of recommendations for management practices so that the pamphlet would be of interest to coconut planters over all the country.

XI. SUMMARY

The dreadful cadang-cadang disease, limited at present to several provinces in the Philippine Islands, presents a serious potential threat to the remaining areas of the Philippines and to other coconut-growing areas of the world. So far as economic losses in the Philippines are concerned, these could probably be overcome in part at least by a replanting and "crop rotation" system. The eventual prevention of the disease will require a sustained research effort over the next fifteen years. Final prevention will be possible only if and when a resistant coconut is found. The search for such coconuts has already begun and suggestions for the further continuation and planning of this work are included in this report.

Basic research is urgently needed to solve the mystery of cadang-cadang transmission from tree to tree and from plantation to plantation, and also to learn more about the nature of its causative agent, now believed to be an insect-borne plant virus.

APPENDIX I

INTERNAL SPOTTING OF COCONUTS

In the manufacture of desiccated coconuts any discoloration of the meat is objectionable. Nuts with spots, occasionally found among normal white ones, have to be eliminated before desiccation. A small percentage, usually below one percent of the total, may have to be removed from conveyor belts at the factories, because of discoloration of the outer side of the meat. This defect can only be seen after the skin, which covers the meat, has been removed.

A few years ago, Mr. Hans Rothkirch, Assistant Manager of the Franklin Baker Company of the Philippines in San Pablo, noticed in certain shipments of coconuts from the Island of Mindoro an alarmingly high percentage of discoloration. The expert, with whom Mr. Rothkirch discussed this problem, investigated plantations on Mindoro in the localities of Calapan, Pinamalayan, and their vicinity. Copra producers, who received nuts from these localities, also complained that the oil from Mindoro nuts was cloudy in appearance. These producers did not notice the internal spots, because in the processing of copra the skin is never peeled.

The expert found a high percentage in some cases over 80 percent of the nuts, affected with internal spotting. However, in one of the plantations where a very high incidence had been recorded two years ago by Mr. Rothkirch, hardly any spotting could be found in 1960. This seemed to indicate that internal spotting is not a simple infectious disease or genetic affliction, but more likely a manifestation of a physiological condition, or a result of a combined action of an infectious agent and environmental conditions. It should be added here that Mindoro has some of the highest-yielding coconut palms in the Philippines.

After the trip to Mindoro, nuts in other regions of the country were also peeled to check for the possible occurrence of spots. A small number of nuts from plantations around Legazpi and Guinobatan, Albay, on Luzon Island, also showed the peculiar symptoms. Further studies and surveys were suggested to establish whether this condition is prevalent throughout the Philippines and to find the frequency of its occurrence. It is hoped that similar studies will also be made in other coconut-growing areas, and that the conditions governing the internal spotting will be recognized and a method of prevention found.

APPENDIX II

BOANG DISEASE

The boang disease, which results in deformation and emptiness of coconuts, has devastated a large plantation on Mindanao.

"Boang" in the Bohol language means empty, and the name refers to coconuts without useful contents. The disease has also been called "crazy nuts", because of the peculiar distortions and very light weight of fairly large nuts. In 1954, boang attacked an estimated 3,500 of 16,000 trees in the most severely affected block of the Tiblawan Plantation. In 1960 the estimated number of diseased trees in the same block was 7,000. It should be added that in this estimate only trees with visibly distorted or completely spoiled nuts were considered as diseased. If trees bearing but one damaged nut had been counted as diseased, and if the early stages of boang could have been observed without the splitting of suspected nuts, the number of trees with boang probably would be more, nearly 90 percent of the total. This estimate is based on the finding that many nuts collected during the survey from so-called healthy trees were found to have early symptoms of the disease.

Typical boang nuts are either completely empty or very small. The shell is very thick, hard, strong, and small, forming pigmy-sized nuts. The kernel is either completely absent or has globular protuberances. Some nuts contain fermented "water" while others are dry inside. The copra, where present, is of very poor quality, brownish, and deteriorates further during the drying process.

The cause of boang has not yet been experimentally determined and the following is being presented as a working hypothesis. The differences in the appearance of fermented nuts, particularly the multicolored bacterial colonies, seemed to indicate that bacteria and fungi were but secondary invaders of the boang nuts. The tiny channel which was found in almost every distorted nut and in some nuts that at first were believed to be healthy, might serve as the point of entry for various bacteria and fungi. It appeared likely that a small insect caused the damage and that its eggs were being deposited in the buttons at the time of pollination. Many buttons failed to develop and became abortive, so that the number of developing nuts was much reduced. A toxic substance could have been secreted by the developing larva and might have caused the distortion of the affected nuts. Afterward, the larva or perhaps the adult insect bored the narrow channel leading outward, through which it emerged.

If this occurred late in the development of a nut, invasion of micro-organisms could cause fermentation of the water but not necessarily destruction of the copra. Earlier emergence of the causal insect could permit longer action of secondary invaders, resulting in complete spoilage of the interior of the nuts. This hypothesis was supported by the finding that in many healthy-appearing nuts, the shell was normal, except for a very small area surrounding the inner end of the tiny channel.

The cause of boang is now under investigation. At the devastated plantation in Tiblauan, Governor Generoso, Davao Province, two technical people from the BPI have begun to work on the possible causes and prevention of the disease.

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Map of Bondoc Peninsula, Quezon Province, Luzon